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Original Article

Cetacean–fishery interactions in Galicia (NW Spain): results and management implications of a face-to-face interview survey of local fishers

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Galicia (NW Spain) is an important fishing region with a high potential for cetacean–fishery interactions. Cetacean depredation on catch and damage to fishing gear can potentially lead to substantial economic loss for fishers, while cetacean bycatch raises conservation concerns. With the aim of gathering information on the types and scale of interactions and of suggesting possible management strategies, we conducted face-to-face interviews with fishers in local fishing harbours, in particular to identify specific problematic interactions and to quantify the level of economic loss and bycatch rates associated with these interactions. We found that cetacean–fishery interactions are frequent, although damage to catch and fishing gear by cetaceans was mostly reported as small. Nevertheless, substantial economic loss can result from common bottlenose dolphins (*Tursiops truncatus*) damaging coastal gillnets and from short-beaked common dolphins (*Delphinus delphis*) scattering fish in purse-seine fisheries. Cetacean bycatch mortality was reported to be highest for trawls and set gillnets, and probably exceeds sustainable levels for local common and bottlenose dolphin populations. Although interview data may be biased due to the perceptions of interviewees, and therefore should be interpreted with care, the methodology allowed us to cover multiple sites and fisheries within a reasonable time frame. Minimizing cetacean–fishery interactions requires the implementation of case-specific management strategies with the active participation of fishers. For set gillnet and purse-seine fisheries, the use of acoustic deterrent devices (pingers) may prevent cetaceans from approaching and getting trapped in the nets. For trawl fisheries, where bycatch appears to be particularly high at night in water depths of 100–300 m, possible solutions include the implementation of time/area closures and the relocation of some fishing effort to deeper waters.

Keywords: cetacean–fishery interactions, depredation, dolphin bycatch, fisher participation, fishers' opinions, interview survey.

Introduction

Cetacean–fishery interactions remain a cause for concern, with cetacean bycatch being considered a serious threat to cetacean populations world-wide, particularly if threatened species are affected (IWC, 1994). In addition, damage to fishing gear and loss of catch (although the latter is difficult to prove) can potentially lead to substantial economic loss for fishers, especially in areas with acute conflict. Although interactions can be beneficial for some fisheries, for instance in purse-seining where the presence of dolphins is used as a cue to detect fish concentrations (e.g. Allen, 1985), the majority of reports describe adverse effects, i.e. catch loss and gear damage through cetacean depredation (Lauriano *et al.*, 2004; Gilman *et al.*, 2006; Brotons *et al.*, 2008a; Gazo *et al.*, 2008; Rocklin *et al.*, 2009; Silva *et al.*, 2011; Bearzi *et al.*, 2011) and scattering of fish (Wise *et al.*, 2007). In Mediterranean waters, Bearzi *et al.* (2011) estimated the mean economic loss of artisanal trammelnet fishers as €2561 per year, and Brotons *et al.* (2008a) calculated that trammelnet fishers may lose around 5.3% of their total catch value due to interactions with cetaceans.

Galicia (41°48'– 43°47'N), situated in the northwest corner of the Iberian Peninsula (Figure 1), is the most important Spanish fishing region, accounting for almost half of the Spanish fleet and landings in 2010–2011 (Galician Institute for Statistics, 2013; Spanish Ministry of Agriculture, Food and Environment, 2013). Cetacean–fishery interactions are frequently observed in the region, involving a large variety of gears and cetacean species (Aguilar, 1997; López *et al.*, 2003; Pierce *et al.*, 2010; Fernández Contreras *et al.*, 2010; Fernández *et al.*, 2011a, 2011b). The short-beaked common dolphin (*Delphinus delphis*) is the most abundant and frequently sighted cetacean species in the area, followed by the common bottlenose dolphin (*Tursiops truncatus*), which mainly inhabits the coastal inlets (rías) of South Galicia. Other frequently sighted species include long-finned pilot whales (*Globicephala melas*), striped dolphins (*Stenella coeruleoalba*), harbour porpoises (*Phocoena phocoena*), Risso's dolphins (*Grampus griseus*) and other large toothed and baleen whales (López *et al.*, 2002, 2004; Pierce *et al.*, 2010; Spyrakos *et al.*, 2011).

López *et al.* (2003) suggested that the bycatch mortality of common and bottlenose dolphins in Galician waters almost certainly substantially exceeds the maximum bycatch mortality rate (1.7% of the best available population estimate) recommended by ASCOBANS ((Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas), United Nations Environment Programme, New York, 17 March 1992). Catch loss and gear damage due to interactions with cetaceans have also been reported in the area (Aguilar, 1997; López *et al.*, 2003) although, to date, no detailed assessment of the extent and negative effects on fisheries has been carried out.

Cetacean conservation on the one hand and the interests of fishers on the other provide a classic example of a user–environment conflict (Proelss *et al.*, 2011) that requires a holistic management approach in order to find an acceptable solution for all parties involved. The first important step for an effective management strategy is the clear identification of specific problematic interactions, i.e. the fisheries and/or marine areas in which interactions are most prevalent, and the cetacean species that are most involved.

We conducted a face-to-face interview survey to collect data on the experiences and opinions of fishers. Apart from making use of fishers' ecological knowledge (FEK), the co-operation with fishers in scientific research also allows for the establishment of partnerships between scientists and fishers—which is thought to increase data quality, create buy-in among stakeholders and facilitate fishers' support for future management strategies (Johnson and van Densen, 2007).

As explained above, previous studies of cetacean–fishery interactions in Galician waters mainly focussed on the assessment of cetacean bycatch, while adverse effects on fisheries received little attention. Therefore the main objective of our interview survey was to obtain a holistic view of cetacean–fishery interactions by assessing all types of interactions ("positive" and "negative") as observed by Galician fishers, determining the types of gears and cetacean species most involved, and fishing areas (geographical location, water depth and distance to coast) where these interactions mainly occur. We further wanted to quantify the economic loss and bycatch rates associated with cetacean–fishery interactions and identify which mitigation methods were being applied by fishers. Finally, based on the results, we suggest possible management and mitigation strategies for specific cases.

Methods

Study area and local fisheries

Galicia's coastline (about 1200 km in length) is characterized by a series of large, coastal inlets (rías) (Fariña *et al.*, 1997), the size and orientation of which affects the frequency and intensity of the seasonal upwelling events which boost this area's productivity. The four Southern rías are much larger and oriented towards the southwest, while the Northern rías are smaller and more exposed to the oceanic influence, displaying a variety of orientations (Figueiras *et al.*, 2002; ICES, 2011a). Due to these differences, which also condition the human exploitation of the rías, we have divided our study area into two subareas (North and South Galicia), Punta Queixal (5 km north of the town of Muros) representing the geographic border between the North and South Galician coasts (Fernández *et al.*, 2011a) (Figure 1).

There are 128 fishing harbours along the Galician coast, with Vigo, Ribeira, A Coruña, Burela and Celeiro being the most important in terms of landings (Galician Ministry of Fisheries, 2013). In 2011, the Galician fleet comprised 4734 boats, of which the majority (87.6%) fishes with "minor gears" (small-scale fisheries involving vessels <12m) such as pots, artisanal longlines and a large variety of artisanal gillnets (trammelnets, single-panel bottom-set gillnets and driftnets), targeting fish, cephalopods, crustaceans and bivalves in coastal waters. A substantial proportion (26.3%) of the small-scale fishing fleet is also engaged in shellfish harvesting (with hand- and boat-dredges, rakes or manual collection). Most small-scale fishing boats are polyvalent, i.e. they shift between gears depending on the season.

Littoral, medium- to large-scale fisheries (vessel length ≥12 m) only account for 12.4% of the Galician fleet. These vessels target shoaling pelagic and demersal species with purse-seines, bottom trawls, longlines and large bottom-set gillnets mainly in Galician waters, but also off Asturias, Cantabria, the Basque Country and outside Spanish waters (in the latter case, <5% of the Galician fleet) (Galician Ministry of Fisheries, 2010, 2013).

Interview survey

Interview surveys are increasingly applied in ecology due to being an effective methodology for sampling multiple sites and (in the present context) multiple types of fisheries in a comparatively time- and cost-effective way (White *et al.*, 2005; Moore *et al.*, 2010) that would not be possible otherwise. Furthermore, interviews offer the possibility of obtaining valuable insights into the characteristics of local fisheries and their interactions with the marine environment (Johannes *et al.*, 2000), including preliminary data on bycatch rates (e.g. López *et al.*, 2003; Moore *et al.*, 2010).

We conducted a face-to-face interview survey in Galician fishing harbours, applying a stratified sampling procedure, with strata based on the type of fishing gear (seven strata, see Tables 1 and 2). This sampling approach was selected because fishers operating the same gear were assumed to experience similar types of interactions with cetaceans. Fisheries operating outside Spanish waters were not included in order to delimit the study area. Shellfish harvesters operating manual dredges and rakes were also excluded since interactions with cetaceans were assumed to be unlikely. To get a representative sample of Galician fisheries we aimed for a proportional sample, i.e. the sample size (number of vessels) for each stratum

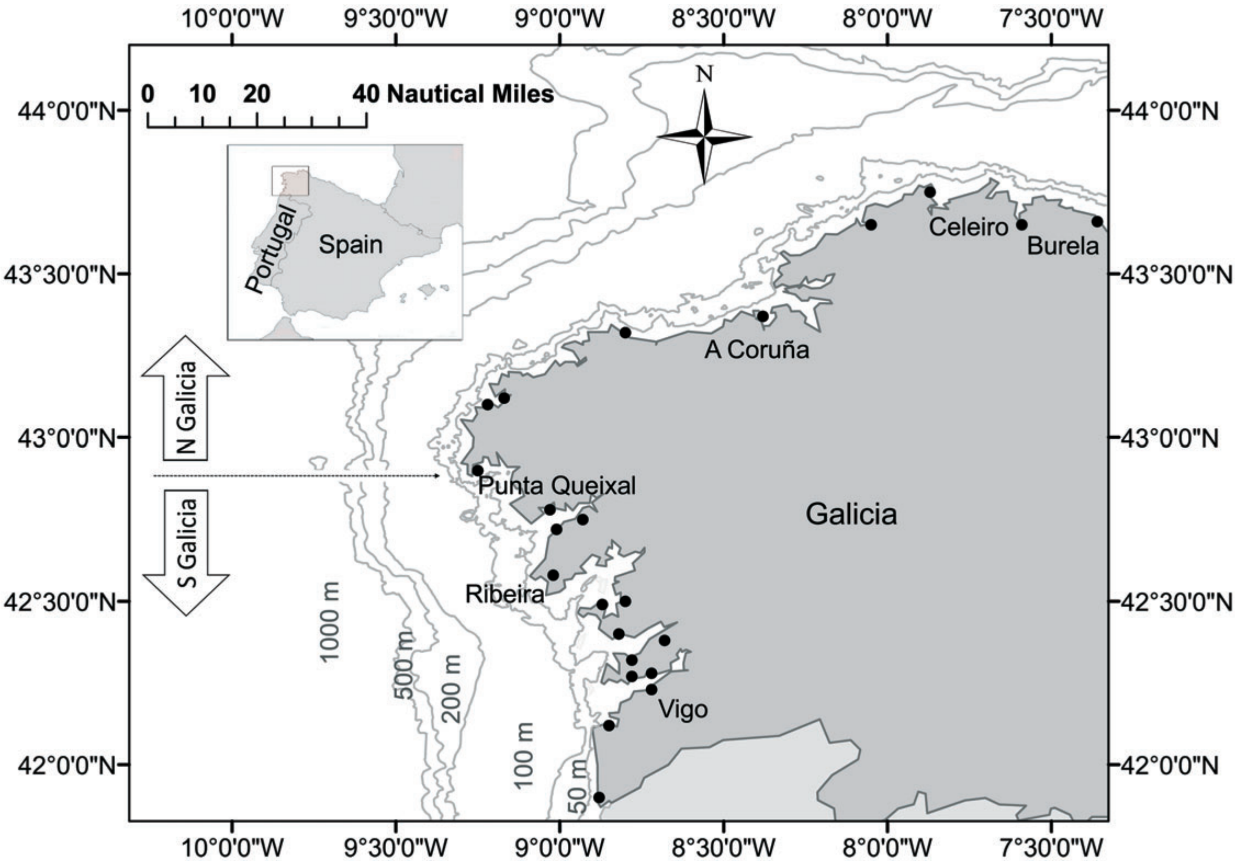

Figure 1. Map of the study area (Galicia, NW Spain). Black dots indicate harbours where interviews were conducted.

being proportional to the overall composition of the sampled fleet. Many harbours in Galicia specialize in certain fishing gears, especially the smaller harbours. Therefore, in order to get sufficient samples for each stratum, we selected harbours (the primary sampling units) according to their representativeness for a certain fishing gear (thus selecting 23 out of 128 harbours) and then sampled boats (secondary sampling units) opportunistically, i.e. we targeted all fishers present and available for interviewing, within the selected harbours (Lauriano *et al.*, 2009). In order to maximize the number of interviews for each sampling day, timing of interviewing was adjusted to the seasonal and daily routine of the fisheries sampled.

We designed a structured questionnaire (the questionnaire form used for this article can be viewed in the Supplementary data online as an Appendix), mainly composed of closed-ended questions, making sure all possible answers were covered and allowing for the answer "don't know", following White *et al.* (2005). Since we were also interested in fishers' opinions and suggestions we included some open-ended questions. In order to optimize response rates, we began with "easier", more general, questions, and asked more difficult and open-ended questions towards the end of the interview. The interviews took 15–20 minutes and were conducted face-to-face by two interviewers who surveyed fishers—if possible the skippers of the vessels—simultaneously, but separately, in the pre-selected harbours. Only professionally active fishers were interviewed. All interviews were kept anonymous and we assured interviewees that all personal data would be treated as confidential. Prior to the implementation of the survey, the questionnaire was pre-tested, first conducting the interview with colleagues and then with a small number of fishers ($n = 20$). Unclear or ambiguous wording was corrected and sequence of questions was adjusted to improve clarity and flow. The survey collected information about: the interviewee's profile (to determine level of experience), characterization of the fishing activity (gears used, main fishing grounds, target species and amount of catch), attitude towards cetaceans (positive, negative, neutral), cetacean sightings (sighted species), occurrence of positive and negative interactions with cetaceans and non-cetacean species, consequences of these interactions for fisheries (description and level of damage, including catch loss through depredation and scattering of fish, gear damage and associated economic loss) and cetaceans (level of bycatch), mitigation measures employed and suggestions for solutions to avoid interactions. To obtain an overview of cetacean–fishery interactions that also accounts for potential seasonal variations, we asked fishers to describe their general experience of such interactions or, in the case of questions that included the estimation of numbers (e.g. catch loss, gear damage and cetacean bycatch), to relate their observations to the last 1–2 years, rather than reporting specific events during their last fishing trip. Catch loss was quantified as the percentage of total catch lost per depredation/scattering event. Economic loss associated with catch loss/gear damage was quantified as the amount of money (in €) lost per year, and bycatch as the number of cetaceans (by species) caught per year (Table 1). When asking about cetacean sightings during the interview, we provided an identification catalogue with colour photographs taken in the area, not labelled with species names, and asked fishers to point to the species seen and indicate the name. Incorrect identification of cetaceans in the catalogue was noted by the interviewer on the

Table 1. List of variables used in the analysis with their description and categories.

	Variables	Description and categories
Interviewee profile & fishery data	harbour	names of all fishing harbours where interviews were conducted
	fisher work experience	low (<5 years), intermediate, high (≥30 years)
	function on board vessel	skipper, crew member
	fishing gear	pair- and otter trawls, purse-seines, surface driftnets, single-panel bottom-set gillnets ("betas"[a], "volantas"[b], "rascos"[b])[c], bottom-set trammelnets, i.e. three panels ("trasmallos"[a], "miños"[a])[c], bottom longlines, pots
	target species	European hake (*Merluccius merluccius*), European conger (*Conger conger*), other large demersal fish, blue whiting (*Micromesistius poutassou*), shoaling pelagic species, i.e. sardine (*Sardina pilchardus*), horse mackerel (*Trachurus* spp) and Atlantic mackerel (*Scomber scombrus*), molluscs (cephalopods and bivalves), crustaceans
	type of fishery	vessel length in metres: small-scale (<12 m), medium- to large- scale (≥12 m)
	mean catch volume	in kilogram/haul: low (<100 kg), intermediate, high (≥500 kg)
	mean water depth	in metres: shallow (<50 m), intermediate, deep (≥100 m)
	mean distance to coast	in nautical miles: nearshore (<12 nm), offshore (≥12 nm)
	main fishing grounds	North Galicia (N-Galicia), South Galicia (S-Galicia)
Cetacean sightings & fishers' attitudes	cetacean sightings (individuals or groups)	common dolphin, bottlenose dolphin, striped dolphin, long-finned pilot whale, harbour porpoise, Risso's dolphin, killer whale, sperm whale, baleen whales
	attitude towards cetaceans	negative, neutral, positive
Interaction	positive interactions	cetaceans indicate fish schools
	negative interactions	catch damage/loss (depredation and scattering of fish) and gear damage by cetaceans and non-cetacean species, cetacean bycatch
	approach gear	cetaceans approach gear (or not)
	catch (%) loss	percentage of catch lost per vessel/interaction event: low (<10%), intermediate, high (≥50%)
	economic (€) loss	percentage of gross income lost per vessel per year: minimal (<10%), significant (≥10%)
	bycatch	occurrence and number of animals caught per vessel per year: minimal (≤ 1), low (2–10), intermediate (11–30), high (>30)
Mitigation	mitigation measures	change of fishing area, scare cetaceans away, wait until cetaceans leave, use of pingers, reduce fishing time, other

[a]Small-scale/artisanal fisheries. [b]Medium- to large-scale fisheries. [c]Different net dimension, mesh size and soak time.

questionnaire, and all species-related information given in the respective interview was excluded from further analysis.

In order to identify the main local fishing grounds, we provided a nautical map for fishers to indicate the approximate geographic location of their usual fishing grounds.

At the end of each interview, we asked fishers to give us their general opinion about the factors that most influence the occurrence/level of cetacean interactions with Galician fisheries. In addition, fishers' narratives (e.g. comments and anecdotes) were recorded, when possible. This qualitative information was collected in order to complement and corroborate the results obtained by the quantitative data analysis.

Data analysis

In order to simplify the dataset and to avoid digit preference, the answers to some questions were grouped into categories (Table 1). If a respondent indicated a range of values, we used the midpoint value. To obtain comparable values for the economic loss associated with catch loss and gear damage for each fishery, we converted the reported monetary loss into the percentage of gross income (estimated from mean catch volume based on the market price of the main target species) lost per vessel per year. Boats were assigned to North or South Galicia according to the geographical location of their main fishing grounds.

To check the reliability of answers we compared the answers for the most important questions (e.g. proportion of interviewees that report negative interactions with cetaceans) collected by one interviewer with the answers collected by the other interviewer. Any significant differences might indicate that our results are biased by an interviewer effect, i.e. unintended influence of the interviewee by the interviewer. We also analysed whether the interviewees' work experience and function on board the vessel had a significant effect on their ability to correctly identify the cetacean species displayed in the catalogue.

Since some interviewees operated more than one type of fishing gear, we recorded multiple responses by the same interviewee for all gear-related questions (e.g. occurrence/consequences of interactions with cetaceans and other species, mitigation measures employed) and analysed these responses separately. For analysis that did not include gear type or other gear-related variables (e.g. interviewee's profile, cetacean sightings, factors influencing interactions and suggestions for solution), only one response per interviewee was included.

Since the final number of interviews per stratum (i.e. type of fishing gear) was not exactly in proportion to the relative fleets' sizes, for the purpose of summary statistics, we weighted the strata, adjusting their relative proportion in the sample to their actual proportions in the surveyed fleet (Table 2). For statistical modelling, gear-type is an explanatory variable and no weighting was necessary.

Generalized linear models (GLMs) were used in order to determine which factors are most influential on the frequency of occurrence of cetacean–fisheries interactions, the extent of associated economic loss and the choice of mitigation methods employed (Chambers and Hastie, 1992; Cameron and Trivedi, 1998; White *et al.*, 2005).

All response variables were binary and a binomial distribution was used with the logit link function if the dataset contained more ones than zeros, and the cloglog link function otherwise. We ran a GLM with all relevant covariates, also including interaction terms between variables, using a backward selection procedure. At each

Table 2. Composition and detailed description of the surveyed fleet (excluding vessels fishing outside Spanish waters and shellfish harvesters) and sample, including the number of vessels and percentages of vessels associated with each type of fishery (stratum), and the weighting factors applied in descriptive analysis.

	Type of fishing gear							
	Trawl	**Purse-seine**	**SPBG**	**Trammelnet**	**Driftnet**	**Longline**	**Pot**	**Total**
surveyed fleet (*N*)								
number of vessels	84	158	343	701	148	762	1071	**3267**
%	2.6	4.8	10.5	21.5	4.5	23.3	32.8	
sample (*n*)								
number of interviews	38	58	52	75	10	25	72	**330**
%	11.5	17.6	15.8	22.7	3.0	7.6	21.8	
weighting factor	0.22	0.28	0.67	0.94	1.49	3.08	1.50	
type of fishery (vessel length):								
small-scale (< 12 m)		6%	60%	80%	100%	60%	87%	
medium- to large-scale (≥ 12 m)	100%	94%	40%	20%		40%	13%	
mean water depth:								
shallow (< 50 m)		63%	43%	68%	92%	56%	78%	
intermediate		31%	26%	29%	8%	12%	19%	
deep (≥ 100 m)	100%	6%	31%	3%		32%	3%	
mean distance to coast:								
nearshore (< 12 nautical miles)	11%	100%	79%	96%	100%	84%	100%	
offshore (≥ 12 nautical miles)	89%		21%	4%		16%		
main target species:								
European hake	11%		43%	1%		23%		
European conger						48%		
other large demersal fish	22%		54%	69%	7%	29%		
blue whiting	34%							
shoaling pelagic fish	33%	100%			93%			
molluscs				17%			81%	
crustaceans			3%	13%			19%	
mean catch volume:								
low (< 100 kg)			50%	85%	59%	29%	86%	
intermediate	12%	13%	38%	12%	33%	63%	14%	
high (≥ 500 kg)	88%	87%	12%	3%	8%	8%		

The characteristics of each type of fishery are summarized for the sample. The percentage of surveyed vessels within each category is indicated.
SPBG = single-panel bottom-set gillnet.

step, non-significant variables were dropped (*F*-Test) and the model was re-run, until all remaining covariates were significant. All variables included in the analysis are listed in Table 1. The variable "harbour" was included in the model to account for any variability between harbours that was independent of gear type. We then validated the final model, checking if the assumptions of homogeneity and independence of residuals were met, also checking for the existence of influential datapoints. For categorical covariates with more than two categories we created dummy variables, in order to investigate which categories of the covariate are significantly different from each other, then applied a Bonferroni correction for multiple comparisons.

A rough estimation of fishery-related cetacean mortality in Galician waters was derived by extrapolating the average annual number of dead animals reported by the fisheries with highest bycatch in the current interview dataset (i.e. trawls, trammelnets and single-panel bottom-set gillnets) to the entire Galician trawl and set gillnet fleets, accounting for the proportion of each fleet that reports to have bycatch.

Statistical analysis was performed using SPSS Statistics 19 (IBM) and, for modelling, Brodgar 2.7.2 (Highland Statistics Ltd).

Results

Between May 2008 and August 2010 we conducted 283 interviews (accounting for 283 vessels) in 23 harbours along the Galician coast, covering around 6.3% of the Galician fleet operating in national waters (4450 vessels; Galician Ministry of Fisheries, 2013). If considering only the fleet of interest (excluding shellfish harvesters), interviews covered 11.6% of vessels (from a total of 3267). Including multiple responses given by the interviewees who operated more than one type of gear, the total sample size was 330 (Table 2). The response rate was high (97%) with only a few fishers ($n = 8$) refusing to take part in the survey because they had no time for the interview. There were no significant differences in answers for the most important questions between the two interviewers, suggesting that interviewer effect was negligible. The factor "harbour" was not significant in any of the GLMs, which indicates that our sampling procedure did not introduce notable bias into our data and that there were no differences between harbours not captured by other variables already included in the analysis (e.g. gear type, fishing area).

Characteristics of the sampled fleet

Fishers interviewed were almost exclusively males (99.3%), between 19 and 65 years of age, who had a mean working experience of 25 years ($SD = 11.45$). The majority (90.7%) reported family links to fisheries. Most fishers interviewed were skippers (73.6%), the remainder being crew members (26.4%).

Table 3. GLM results: all response variables followed a binomial distribution (yes/no).

Response variables	Explanatory variables	χ^2	p	d.f.	n	%dev
negative attitude towards cetaceans	catch and gear damage by cetaceans	104.23	<0.000 1	1	330	27.4
positive interactions	target species	33.91	<0.000 1	6	285	24.9
	water depth	9.33	0.004 9	2		
	presence of DDE	3.07	0.079 8	1		
cetaceans approach gear	gear damage	27.22	<0.000 1	1	313	30.2
	catch damage	7.18	0.007 4	1		
cetacean catch damage	main fishing grounds	16.98	<0.000 1	1	267	31
	target species	63.39	<0.000 1	6		
catch damage by DDE	catch volume	8.85	0.011 9	2	58	20.9
	water depth	6.25	0.043 9	2		
catch damage by TTR	catch volume	21.45	<0.000 1	2	58	26.8
high catch (%) loss (cet)	catch volume	36.62	<0.000 1	2	77	34.7
non-cetacean catch damage	catch volume	6.31	0.042 6	2	232	15.6
catch damage by cephalopods	target species	20.13	0.001 2	5	53	30.5
	water depth	12.66	0.001 8	2		
catch damage by sharks	target species	12.98	0.023 5	5	53	46.1
	water depth	7.22	0.027	2		
high catch (%) loss (non-cet)	catch damage by crustaceans	25.61	0.020 2	1	58	22.8
cetacean gear damage	fishing gear	80.48	<0.000 1	6	229	29.3
gear damage by TTR	fishing gear	16.13	0.002 8	6	66	17.7
gear damage by DDE	fishing gear	14.66	0.011 9	6	89	12.4
significant economic (€) loss (cet)	gear damage by TTR	4.5	0.034	1	73	5.98
non-cetacean gear damage	fishing gear	15.09	0.009 9	6	32	41.9
gear damage by crustaceans	gear damage by crustaceans	7.99	0.004 7	1	29	40.8
significant economic (€) loss (non-cet)	gear damage by conger	4.84	0.027 8	1		
cetacean bycatch (yes/no)	fishing gear	62.99	<0.000 1	6	235	30.5
	water depth	18.59	<0.000 1	2		
bycatch of DDE	fishing gear	11.41	0.048 3	6	83	10.5
bycatch of TTR	type of fishery	12.04	0.000 5	1	83	17.5
mitigation measures (yes/no)	gear damage	21.16	<0.000 1	1	316	46.1
	fishing gear	35	<0.000 1	6		
	catch damage	13.69	0.000 2	1		

Results displayed are as follows: nominal explanatory variables included in the final model, their significance based on χ^2 tests, with p-value (the significantly different categories of each explanatory variable are specified in the Results (*Interactions* and *Mitigation measures*), the degrees of freedom (d.f.), the number of observations (n) and the overall percentage of deviance explained (%dev) by the model. DDE = Common dolphin, TTR = bottlenose dolphin, cet = cetaceans, non-cet = non-cetacean species. For a detailed description of variables see Table 1.

Gillnets were the fishing gear most frequently used (trammelnets 22.7%, single-panel gillnets 15.8% and driftnets 3%), followed by pots (21.8%), purse-seines (17.6%), trawls (otter-trawl 6% and pair-trawl 5.5%) and longlines (7.6%); 63.2% of our interviewees were fishing in South Galician waters, 30.3% in North Galicia and the remaining 6.5% along the Asturian, Cantabrian and Basque Country coasts.

High catches (≥500 kg/haul) were mostly reported by trawl fishers (blue whiting, large demersal fish and shoaling pelagic species, mainly in deep offshore waters) and purse-seiners (shoaling pelagic species in nearshore waters). Fishers operating longlines and single-panel bottom-set gillnets mostly targeted hake, conger and other large demersal fish in nearshore waters and achieved low to intermediate catches (<500 kg). Trammelnets, pots and driftnets were mostly set in shallow waters (<50 m), achieving small catches (<100 kg); the former two targeted cephalopods, crustaceans and large demersal fish, while the latter caught exclusively shoaling pelagic fish (Table 2).

Cetacean sightings: species composition and fishers' attitudes towards cetaceans

Based on weighted interview data, the cetacean species most frequently sighted were bottlenose dolphins (40.1% of sightings) and common dolphins (35.4%), followed by non-identified cetaceans (10.8%), harbour porpoises (5.2%), long-finned pilot whales (5%), and striped dolphins (1.8%). Risso's dolphins, sperm whales (*Physeter macrocephalus*), killer whales (*Orcinus orca*) and baleen whales were also occasionally sighted (all <1%).

The majority (73.5%) of fishers were able to identify the common cetacean species correctly, independent of their work experience or their function on board the vessel (no significant differences were detected).

Fishers' attitudes towards cetaceans were mostly neutral (70.6%); they reported that animals do not disturb fishing operations, at least not with their gears, although they acknowledged that they may be problematic for other gears. Negative opinions about cetaceans (17.4% of respondents) were significantly related to catch- and gear damage (Table 3). Fishers with a positive opinion (12%) frequently replied that they like to see cetaceans, because "they break their routine" and that "their presence indicates the presence of fish schools".

Interactions

Based on weighted data, slightly over one-third (38.6%) of fishers reported having interactions with cetaceans, the majority (83.5%) being classified as negative.

Positive interactions were mostly associated with common dolphins, primarily because dolphins were associated with the presence of schools of pelagic species in intermediate water depth (Table 3).

Negative interactions comprised damage/loss of catch (depredation and scattering of fish; 42.2%), gear damage (34.3%) and cetacean bycatch (23.5%). In contrast, only 0.5% of fishers considered bycatch to be their most serious cetacean-related problem.

Fishers reported damage to catch and gear caused by cetaceans (52.3% of damage events), but also by other animals (47.7%), such as bony fish (conger), elasmobranchs (blue shark, *Prionace glauca*; shortfin mako, *Isurus oxyrinchus*), cephalopods (common octopus, *Octopus vulgaris*; European squid, *Loligo vulgaris*; common cuttlefish *Sepia officinalis),* crustaceans (green crab, *Carcinus maenas*; parasitic isopods *Cymothoa* spp.; lobster, *Homarus* spp.), starfish and seagulls (Figure 2a and b).

Cetaceans as well as non-cetacean species were described as feeding on catch or bait trapped in the gear (depredation). Fishers reported being able to identify which group was responsible for depredation, either through direct observation or based on the nature of the damage. They mentioned that cetaceans normally tear the body of the fish, leaving characteristic bite marks and often just the fish head in the nets, whereas sharks typically bite the fish in half leaving clean borders. The presence of several small bites on the fish body indicate depredation by conger, cephalopods and crustaceans. While the latter frequently bite small holes into the nets during feeding, cetaceans and sharks may tear medium-sized to large holes in the nets when they remove fish. Fishers reported that large sections of the nets can also be torn if cetaceans accidentally get entangled in static nets. In purse-seine fisheries, cetaceans were frequently observed to scatter fish before the net was pursed, while in trawl fisheries they occasionally twisted the gear, resulting in catch loss.

The reported contribution of cetaceans (mainly bottlenose dolphin, followed by common dolphin) to catch damage/loss was considerably lower than the contribution of non-cetacean species (conger, cephalopods, sharks and crustaceans) (36.8% and 63.2%, respectively; Figure 2a), while damage to gear was reported as being more frequently caused by cetaceans than by non-cetacean species (72.1% and 27.9%, respectively; Figure 2b). Cetaceans were sighted close to the gear in the majority of cases when catch damage/loss (89.6% of cases) and gear damage (90%) occurred (Table 3). Longlines and pots were the only gears that were not affected by any type of interactions with cetaceans.

Significantly higher rates of catch damage/loss caused by cetaceans were reported by fishers operating in South Galicia and targeting shoaling pelagic species (Table 3).

Bottlenose dolphin was the main species associated with depredation on catch (61.4% of all reported depredation events), preying primarily on small catches, while common dolphin was reported to be most likely to scatter fish (50% of scattering events) in intermediate water depth, predominantly interfering with fisheries achieving large catches (Table 3).

The reported occurrence of gear damage by cetaceans was significantly higher for artisanal driftnets (100% of the driftnet users reported gear damage; $n = 15$) than for all other gears. Single-panel bottom-set gillnets also had a relatively high proportion of damage by cetaceans (54.3% of single-panel bottom-set gillnet users), while there were no reports of damage to pots (Table 3).

Damage to gear caused by bottlenose dolphin was observed mainly in driftnets and set gillnets, while common dolphin caused net damage mostly in trawls and purse-seines (Table 3).

Catch loss per vessel/interaction event was classified as low (<10% of total catch) by 42.6% of the fishers who had reported catch damage; 41.9% of interviewees reported high catch loss (≥50% of total catch), frequently mentioning that it is not unusual to lose the whole catch when cetaceans interfere with the fishing operation. This was significantly linked to fisheries with high catches (Table 3). Purse-seine fishers estimated that losing the whole catch during a fishing operation is equivalent to a monetary loss of 3500–6000 Euros per event.

The annual economic loss associated with catch damage caused by cetaceans was, however, mostly (77.7% of catch damage reports) reported to be minimal (<10% of gross income) (Figure 3). In only 22.3% of cases, was economic loss reported to be significant (≥10% of gross income), over half (57.1%) of these cases relating to catches of shoaling pelagic species.

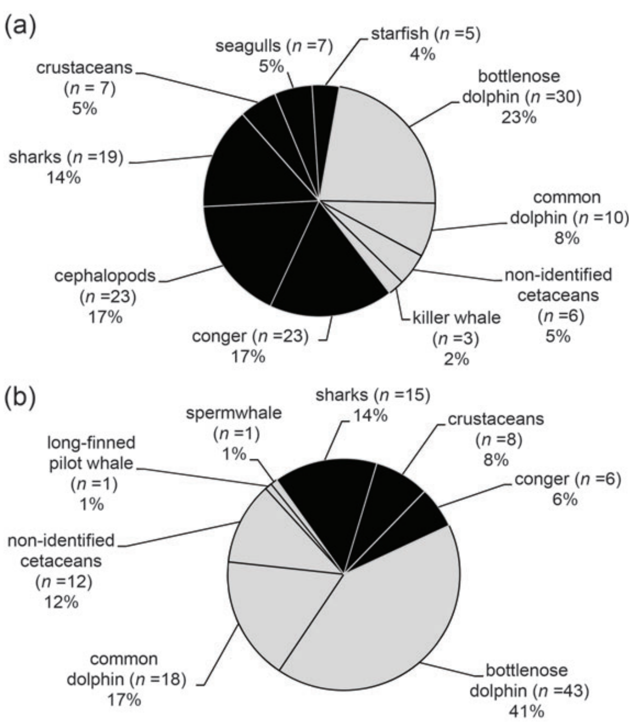

Figure 2. Contribution of cetacean (grey) and non-cetacean species (black) to **(a)** catch damage/loss, and **(b)** gear damage, as reported by interviewees (in percentages).

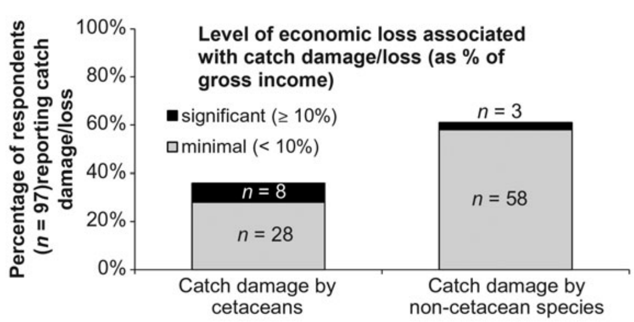

Figure 3. The contribution (in percentages) of cetacean and non-cetacean species to catch damage/loss (a total of 97 interviewees reported catch damage). The level of economic loss (as percentage of gross income lost per vessel per year) associated with cetacean and non-cetacean catch damage is also illustrated, grey referring to minimal (<10%) and black referring to significant (≥10%) economic loss.

Economic loss associated with gear damage by cetaceans was mainly reported to be minimal (72.9% of gear damage reports; Figure 4). Significant economic loss (27.1%) was strongly related to gear damage by bottlenose dolphins (Table 3). Although fishing gear was not significant in our model, high economic loss was a lot more common in coastal gillnets (93.8% of cases) than other gears.

Depredation by non-cetacean species was reported to be mainly associated with low catches, octopus mostly preying on catches of crustaceans in deep waters and sharks preying on hake in intermediate water depth, while gear damage was mainly associated with crustaceans damaging pots (Table 3).

Economic loss associated with depredation and gear damage by non-cetacean species was reported to be significant in only 4.9% ($n = 3$) and 12.9% ($n = 4$) of interaction events with these species, respectively (Figures 3 and 4). The main non-cetacean species causing significant catch and gear damage were conger (44.4% of these cases),/crustaceans (33.3%; Table 3), cephalopods (21.1%) and starfish (10.5%).

Estimated versus perceived loss

At the end of each interview, fishers who reported suffering catch and/or gear damage by cetaceans were asked if they perceived this damage as problematic, i.e. significant for their activity, 62.5% of fishers answered "yes". This percentage markedly exceeds the proportion of interviewees whom we estimated to suffer significant economic loss.

Cetacean bycatch

One-fifth (20.2%) of fishers reported incidental bycatch of cetaceans, mainly in trawls, purse-seines, trammelnets (trasmallos and miños) and single-panel bottom-set gillnets (betas and volantas), identifying common dolphin as the species most frequently bycaught (53.3%), followed by non-identified cetaceans (23.3%) and bottlenose dolphin (18.3%). Pilot whale, striped dolphin and harbour porpoise represented only 5.1% of bycatch reported during interviews (based on weighted data). Almost half (49%) of the interviewees who reported cetacean bycatch declared that they catch fewer than 10 animals per year, 44.4% had minimal bycatch (≤1 animal/year), and only 6.6% said that bycatch was high (>30 animals/year). In our model, the probability of cetacean bycatch was highest for trawls, purse-seines and trammelnets, and generally increased with increasing water depth (Table 3). Cetacean bycatch reported by trawlers (mainly of common dolphins) was concentrated in waters of 100–300 m depth, while for trammelnets and purse-seines bycatch mainly occurred in shallower waters (<100 m). Bycatch in single-panel bottom-set gillnets occurred mainly between 50 and 300 m without any clear trend (Figure 5). Bycatch of bottlenose dolphins was significantly related to small-scale fisheries (Table 3). According to fishers, animals encircled in purse-seines usually survived, either by escaping unaided or being helped to escape by the lowering of the corkline.

Of those fishers reporting any bycatch, trawl fishers reported catching 12 animals per year on average, and fishers operating fixed gillnets reported catching two (trasmallos and volantas) or three (miños and betas) animals per year on average. To estimate total bycatch by the whole Galician trawl and set gillnet fleets, we first calculated the number of boats within each sector which would have bycatch (68.4% of 84 trawls, 30% of 363 trasmallos, 54.5% of 39 volantas, 52.4% of 338 miños and 25% of 301 betas), and then multiplied these numbers with the average annual bycatch number of each sector. Summing up all products, this would give a total estimate of 1707 cetaceans killed by Galician fisheries each year (159 common dolphins, 136 bottlenose dolphins, 73 long-finned pilot whales, 40 harbour porpoises and 1299 non-identified cetaceans).

Mitigation measures

Almost half (42.6%; weighted percentage) of the interviewees who reported negative interactions also reported the application of mitigation. The main measure was to navigate to alternative fishing grounds away from the cetaceans (44.4% of fishers that used mitigation measures). Another strategy was scaring the cetaceans away from the vessel (28.8%), for instance by making noise, using firecrackers, throwing stones at the animals or hosing them with seawater. Some fishers mentioned that they postpone the fishing

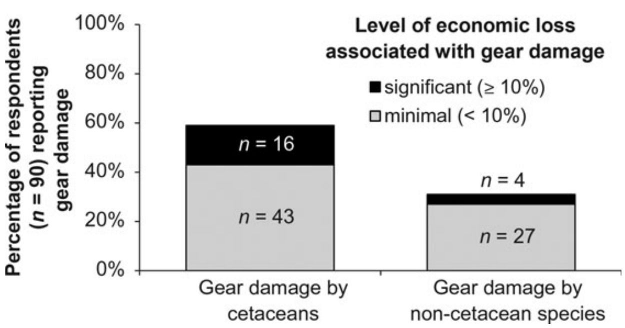

Figure 4. The contribution (in percentages) of cetacean and non-cetacean species to gear damage (a total of 90 interviewees reported gear damage). The level of economic loss (as percentage of gross income lost per vessel per year) associated with cetacean and non-cetacean gear damage is also illustrated, grey referring to minimal (<10%) and black referring to significant (≥10%) economic loss.

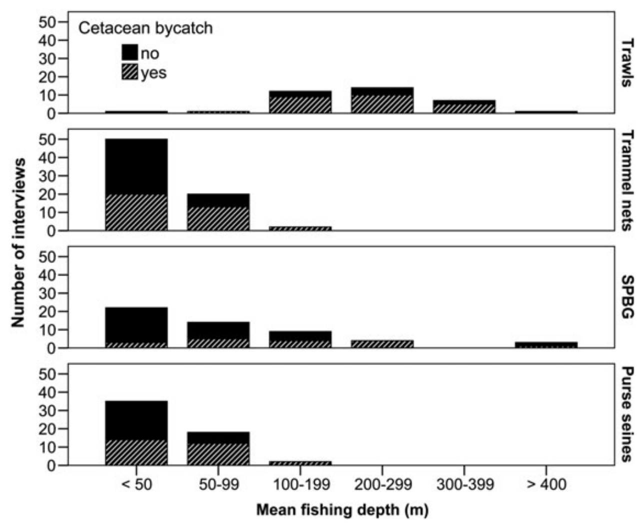

Figure 5. Reported depth distribution (mean fishing depth in metre) of fishing activity and occurrence of cetacean bycatch for trawls, set gillnets (trammelnets and single-panel bottom-set gillnets: SPBG) and purse-seines. The bars represent the number of interviews in each depth category. The proportions of interviews reporting cetacean bycatch are highlighted with diagonal white stripes, while the proportions of interviews with no bycatch reports are highlighted in black.

operation until the cetaceans leave the area (16.4%) and only very few interviewees reported that they reduce the fishing/soak time (7.1%) or use pingers (3.3%) to avoid interactions.

Mitigation measures were used significantly more frequently by fishers suffering gear and catch damage, compared with those suffering no damage, particularly by those using driftnets and purse-seines (Table 3), and when scattering of fish was reported as the main problem.

Influential factors and fishers' suggestions for solutions

When asking fishers about the most important factors influencing the number of interactions with cetaceans, they indicated that the type of fishing gear used was the most influential factor (56.6%). Gillnets were identified as the most problematic gear. Another factor frequently indicated was the catch target species (22%), namely fishing for shoaling pelagic species. Of the interviewees, 8.1% believed that season was also an important factor, with interactions occurring more frequently in summer and spring, and 6.8% mentioned that fishing area may be influential, interactions occurring more frequently nearshore than offshore. Other factors mentioned (<5%, in each case) included fishing time/duration, weather, water depth, cetacean behaviour, moon cycle and resource availability.

Relatively few fishers (15.7%) provided suggestions about how to solve the problem of cetacean–fisheries interactions. Suggestions included measures to benefit fisheries and cetaceans in approximately equal proportions. The former ranged from deterring cetaceans from approaching the gear (for instance with acoustic deterrent devices) and financial compensation, to a few rather extreme suggestions, namely the hunting and deliberate killing of cetaceans to reduce the local population.

Measures to benefit cetaceans mainly comprised the prohibition of fishing gears with high bycatch levels, a large-scale reduction of fishing effort and the establishment of cetacean conservation areas, where fishing is restricted. The need for alternative "cetacean friendly" fishing methods and more environmental education was also emphasized.

Discussion

Cetacean species sighted and their interactions with fisheries

Quantitative analysis, as well as qualitative information provided by Galician fishers, suggests that the occurrence/level of cetacean interactions is primarily influenced by type of fishing gear, target species and fishing area. Coastal demersal gillnet fisheries and purse-seine fisheries for shoaling pelagic species are the main fisheries affected by catch/gear damage, while offshore trawling causes the highest cetacean bycatch mortality.

The cetacean species sighted by the respondents and their relative frequency of occurrence are consistent with those previously described by other authors for the North West Iberian Peninsula using a variety of methods, including sightings from vessels and from the coast, and interviews (Aguilar, 1997; López *et al.*, 2002, 2003, 2004; Pierce *et al.*, 2010; Spyrakos *et al.*, 2011).

As in several similar studies, bottlenose dolphin was reported to be the species most strongly associated with depredation and gear damage, particularly for set gillnets (Aguilar, 1997; Lauriano *et al.*, 2004, 2009; López *et al.*, 2004; Brotons *et al.*, 2008a; Rocklin *et al.*, 2009; Bearzi *et al.*, 2011). Common dolphins were also frequently mentioned to interact with the fishing activity, but primarily with purse-seines. Although the report of interaction frequency was generally high in our survey, the majority of interviewees had a neutral or positive attitude towards cetaceans, and the economic loss resulting from negative interactions was mainly classified as low. This contrasts with the perception of fishers affected by catch loss and gear damage who mostly classified cetacean–fishery interactions as "problematic". This discrepancy between the estimated and the perceived impact of cetacean–fishery interactions, which was also observed by Silva *et al.* (2011) and Wise *et al.* (2007), may be linked to the fact that fishers who frequently experience negative interactions with cetaceans might tend to exaggerate the real economic impact in order to draw attention to their situation, or may perceive the interviews as an opportunity to influence decision-making with respect to governmental monetary compensations for catch loss and gear damage (Bearzi *et al.* 2011). In contrast, cetacean bycatch that was reported by almost one-quarter of fishers, was rarely considered a serious problem, most likely because (apart from occasional gear damage) bycatch did not have a direct negative impact on fishers' profit and/or because fishers may be afraid of the implementation of bycatch reduction measures that restrict their activity.

However, there were two circumstances where dolphins were reported to have a significant negative impact on fisheries: interactions between purse-seiners and common dolphins and interactions between bottlenose dolphins and coastal gillnets. Purse-seine fisheries target sardine, one of the main prey species of common dolphins in Galician waters (Méndez Fernández *et al.*, 2012; Santos *et al.*, 2013). They frequently use observations of dolphins as a cue for the presence of a large fish school, although, in contrast, some interviewees indicated that if dolphins are in an area, they avoid it. Fishers reported that dolphins cause scattering or sinking of entire fish schools, frequently leading to the complete loss of the catch for the affected haul. Such occurrences are plausible and are probably directly linked to the fish school's awareness of the presence of a predator (Wise *et al.*, 2007). Nevertheless, due to low frequency of interactions and stable catch rates, Wise *et al.* (2007) concluded that small cetaceans are not harmful to purse-seine fisheries in Portuguese waters. Our study, however, indicates that catch may be significantly reduced if cetaceans interact during purse-seining. In fishing areas with high dolphin abundance such interactions are likely to occur and associated economic losses may therefore be substantial.

Gear damage by bottlenose dolphins in particular was considered to be a problem for fishers who target shoaling pelagic species with artisanal surface driftnets, and hake and other large demersal fish with single-panel bottom-gillnets inside the South Galician rías. Both types of fish are important in the diet of bottlenose dolphins (Santos *et al.*, 2007). As the dolphins attempt to remove fish trapped in the nets, they frequently tear large holes in the net (Brotons *et al.*, 2008a). Fishers also indicated that dolphins sometimes get entangled in the gear and damage larger sections of the net. Fishers mentioned that net repair is too expensive and that they usually continue using the damaged gear (which becomes ineffective, reducing catch) until the end of the fishing season before replacing it.

In contrast, fishers reported that depredation on catch by bottlenose dolphins occurred less frequently than gear damage by the same species in setnet fisheries. This may indicate that dolphins mainly prey on fish in the water column and only occasionally take fish from nets as an additional food source, which was also hypothesized by Rocklin *et al.* (2009).

It was not only cetaceans that were reported to interact with fisheries: damage of catch by crustaceans, cephalopods, conger and sharks was more frequently mentioned than damage by dolphins in coastal small-scale net fisheries. Cephalopods were reported to consume all the shellfish from gillnets and pots leaving only the shells, while crustaceans and conger were reported to cause significant monetary loss (although only occasionally). It is therefore important to note that non-cetacean predators can also contribute substantially to catch loss and gear damage (Rocklin *et al.*, 2009; Bearzi *et al.*, 2011). The types of catch and gear damage described by our interviewees were consistent with those reported by similar studies (Secchi and Vaske, 1998; Brotons *et al.*, 2008a; Gazo *et al.*, 2008; Gönener and Özdemir, 2012) and we are therefore confident that fishers were able to identify types of damage correctly. However, it is possible that, since dolphins were more visible to fishers than other predatory species, some damage to catch and gear attributed to dolphins may be caused by other species. Seasonal or spatial variation in fish abundance or catchability, as well as oceanographic conditions, may be also responsible for reduced catches (Lauriano *et al.*, 2004). Gear damage may also arise when the nets get caught on the seafloor or collect marine debris, as mentioned by some interviewees.

Galician fishers also reported occurrence of cetacean bycatch, which was classified as particularly high for trawls, purse-seines and trammelnets, mainly affecting common dolphins. This is consistent with the findings of Aguilar (1997), Fernández Contreras *et al.* (2010) and López *et al.* (2003) for the same area. The high bycatch frequency of common dolphins in trawlnets is probably linked to the fact that pair-trawlers off Galicia usually operate in water depths between 125 and 700 m, mainly targeting blue whiting, horse mackerel, Atlantic mackerel and hake (Fernández Contreras *et al.*, 2010), which overlaps with both important prey species of common dolphins and the range of water depths over which the species occur (López *et al.*, 2004; Pierce *et al.*, 2010; Santos et al., 2013). Purse-seines can be considered to have a low impact on cetacean mortality due to the high survival rate of encircled dolphins (Aguilar, 1997; Wise *et al.*, 2007; Hamer *et al.*, 2008).

In contrast, bottlenose dolphins and harbour porpoises, due to their generally more coastal distribution in Galician waters (López *et al.*, 2004; Pierce *et al.*, 2010), are more likely to interact with set gillnets. Nevertheless, the reported bycatch rate of these species was relatively low when compared with common dolphins in trawls. Buscaino *et al.* (2009) and Cox *et al.* (2003) both pointed out that bottlenose dolphins frequently interact with gillnets, but rarely get entangled.

Although the bycatch rates reported by Galician fishers may seem to be moderate (mostly $<$10 animals per year), it has to be considered that coastal gillnet fisheries make up a large proportion of the Galician fleet and that the sum of animals killed by this fishery may actually be considerable. Our preliminary estimate of fishery-related cetacean mortality for trawls and set gillnets is 1707 animals per year (of which 159 are common and 136 bottlenose dolphins); see F.L. Read, pers. comm., for a more detailed examination of likely bycatch rates based on the interview data. This total estimate is almost double that derived by López *et al.* (2003), who estimated that 917 cetaceans (trawls and gillnets being responsible for 90.3% of bycatch, i.e. 828 cetaceans) are killed by fisheries in Galician waters each year (including $\sim$ 690 common and 48 bottlenose dolphins in trawls and gillnets only), based on interview data from the late 1990s. It is however difficult to compare the two sets of figures due to the much higher proportion of non-identified cetaceans in the present dataset. In addition, survey designs, including detailed content of the questionnaires, were different.

Based on results from the SCANS-II survey (SCANS-II, 2008), Santos *et al.* (in press) estimated that the common dolphin population in Galicia and adjacent Northern Spanish waters was around 7050, which compares with an estimate of 8140 for Galicia, from opportunistic surveys, used by López *et al.* (2003). Similarly, using SCANS-II results, the bottlenose dolphin population of the North West Iberian Peninsula, excluding animals in the coastal rías, is probably around 3000; López *et al.* (2003) quoted a figure of 660 animals for Galician waters including the rías. Even selecting the smallest bycatch estimates and the largest population size estimates from these given above, the annual bycatch rates for common dolphin (159/8140 or 2.0%) and bottlenose dolphin (48/3000 or 1.6%) are close to the limit of 1.7% recommended by ASCOBANS, and other combinations of these figures would yield annual bycatch rates of $>$10% for common dolphins and $>$20% for bottlenose dolphins. Moreover, analysis of stranded animals in Galicia suggests that fishery-related mortality rates of harbour porpoise may be unsustainable (Read *et al.*, 2012).

Based on the present study, there is cause for concern in the case of both common and bottlenose dolphins. Given the limitations of interviews as a means of collecting reliable quantitative data, we believe that a new study of cetacean bycatch in Galicia, based on on-board observation, is urgently needed.

Mitigation measures and possible management strategies

Interviewees frequently mentioned that "interactions are natural and we have to accept them" and the majority offered no suggestions about solutions. Nevertheless, a number of fishers provided constructive, feasible ideas.

Avoidance of fishing areas where dolphins are present was the most frequently mentioned strategy for all types of fisheries. However, due to the substantial overlap between cetacean feeding areas and preferred fishing grounds, the avoidance strategy obviously has its limitations. Technical solutions, such as acoustic deterrent devices, were mentioned by a few affected fishers.

In our study we were able to identify three specific problematic cetacean–fishery interactions, each of which is likely to need a case-specific management strategy. For set gillnets, which are mostly used inside the South Galician rías, the goals are to reduce bycatch of bottlenose dolphins as well as damage to gear, while in purse-seine fisheries common dolphins need to be deterred from approaching the nets in order to avoid scattering of fish. The use of pingers, which are low-intensity acoustic signal generators emitting mid to high frequency sounds, designed to prevent small cetaceans from approaching fishing gear (Reeves *et al.*, 2001), represent a possible solution, at least for static gears. The devices can be relatively easily attached to nets, although operational issues have been reported, including pinger breakages and interference with fishing operations (e.g. Northridge, 2011; Dawson *et al.*, 2013). Numerous trials showed that pingers can be effective in reducing damage caused by, and bycatch rates of, bottlenose dolphins (e.g. Leeney *et al.*, 2007; Gazo *et al.*, 2008; Brotons *et al.*, 2008b; Read and Waples, 2009; Buscaino *et al.*, 2009; Gönener and Özdemir, 2012) and common dolphins (Barlow and Cameron, 2003; Carretta and Barlow, 2011), although there are also studies that could not demonstrate any obvious aversive reactions of common dolphins to pinger sounds (e.g. Sagarminaga *et al.*, 2006; Berrow *et al.*, 2008). McPherson *et al.* (2004) reported that pingers are not effective in reducing bottlenose dolphin entanglement in gillnets and that the dolphins sometimes behaved aggressively toward pingers, repeatedly attacking them. All of the above-mentioned trials were based on fixed gears. For mobile gears like trawls, the high level of associated noise means that pingers are unlikely to be effective: additional noise is unlikely to enhance detection of the gear (thus permitting avoidance) or to act as a deterrent. Operation of a purse-seine is perhaps not as noisy as trawling, but in addition to the main vessel, motor launches may be deployed to help herd the fish into the net (e.g. ICCAT, 2008) so pingers may not be effective.

Even in the case of static gear, the long-term effectiveness of pingers is still controversial since bottlenose dolphins especially may potentially habituate to the pinger sounds and consequently start to ignore them or even become attracted to them (e.g. Cox *et al.*, 2003; Northridge *et al.*, 2003). For common dolphins, however, no such effect was detected by Carretta and Barlow (2011) who conducted a long-term study over 19 years. The likelihood of habituation may be minimized by using responsive pingers that only activate when receiving cetacean clicks (Leeney *et al.*, 2007) or by periodically modifying pinger emission frequencies (Gazo *et al.*, 2008). Furthermore it is essential to ensure that the signal does not affect the fishery target species in order to avoid negative impacts on catch rates. Since pingers are relatively expensive and may not be affordable for small-scale fishers, governmental subsidies for the acquisition of pingers could be needed.

The possibility of avoiding fishing grounds with high cetacean abundance should be explored. Although it may not be viable if dolphins favour the areas with highest fish abundance, there may be differences between species and size classes targeted by fisheries and those preferred by dolphins that would permit some spatial separation.

For trawl fisheries, the mitigation of dolphin bycatch is the main objective. There are certain operational factors that can influence bycatch: incidental capture is more likely to occur in shallow waters (<300 m) and during nocturnal fishing (Morizur *et al.*, 1999; López *et al.*, 2003; Fernández Contreras *et al.*, 2010). Interviewees reported that most dolphins were captured in water depths between 100 and 300 m. Time/area closures can be effective when patterns of bycatch are predictable in time and space (Murray *et al.*, 2000), and therefore the relocation of some trawling effort to waters deeper than 300 m and imposition of limits on trawling in waters shallower than 250 m, as suggested by Fernández Contreras *et al.* (2010), combined with a reduction of nocturnal trawling (López *et al.*, 2003) could dramatically reduce cetacean bycatch in Galicia. However, since few of the fishers interviewed fished in deeper waters, we cannot be sure that cetacean bycatch rates of trawlers in deeper waters would be lower. The impact of any measures designed to reduce bycatch clearly needs to be monitored, preferably using on-board observers.

The suitability of interview surveys to assess cetacean–fishery interaction

Our qualitative research results are in accordance with quantitative findings for the area (Aguilar, 1997; López *et al.*, 2002, 2003, 2004; Pierce *et al.*, 2010; Fernández Contreras *et al.* 2010; Spyrakos *et al.*, 2011), showing that fishers' ecological knowledge can serve as a useful data source that may also be valuable for wildlife management (Johannes *et al.*, 2000). Nevertheless, information based on reports from fishers (like all interview data) may be potentially influenced by the opinions, perceptions and personal interests of the interviewees (Bearzi *et al.*, 2011). Therefore the damage and bycatch rates indicated by our interviewees should be interpreted with care as economic loss may be overestimated, while bycatch rates are likely to be underreported by fishers.

Nevertheless, interview surveys can be particularly useful where extensive scientific studies may be impractical or financially unfeasible (Johannes, 1998), as is the case for cetacean–fishery interactions that usually occur in remote locations over a wide geographic area. Interview surveys are clearly less costly and time-consuming than on-board sampling and allow for a wide geographic coverage and sampling of multiple gears at the same time (White *et al.*, 2005). In our study we covered more than 5% of the fishing fleet of interest, which is in accordance with the minimum sample size recommended for interview surveys by Czaja and Blair (2005). Furthermore, by applying a stratified sampling strategy (White *et al.*, 2005; Moore *et al.*, 2010), we ensured the sample was reasonably representative of the entire Galician fleet, covering all types of fisheries operating in coastal and offshore waters that are possibly affected by interactions with cetaceans.

The assessment of cetacean–fishery interactions only by on-board observers would be financially and logistically unfeasible. Based on a fleet size of 3267 vessels fishing 5 days a week, around 42 610 observer days, would be needed every year to monitor 5% of the fleet activity, i.e. requiring 163 full-time observers. Clearly, this is a maximum estimate (some vessels probably fish fewer days per week or only during certain seasons) and observations could be focused on those fishing activities most likely to generate interactions with cetaceans. López *et al.* (2003) estimated that a minimum of between 500 and 2000 observer trips per year would be needed to quantify cetacean bycatch in Galician fisheries. Nevertheless, the need for additional data sources is apparent. For routine monitoring, some combination of vessel-based observations by trained observers in a small fraction of the fleet, interview surveys and (as recently trialled in several studies, see ICES, 2011b) on-board video cameras may provide the best solution.

We chose face-to-face interviews because, in contrast to telephone or postal surveys, they create more confidence between interviewer and respondents, allowing for good quality of recorded responses, a high response rate and, consequently low non-response bias (i.e. difference in the answers of respondents from the potential answers of those who did not answer; Lien *et al.*, 1994; Czaja and Blair, 2005; White *et al.*, 2005). A common point of criticism of this methodology is the interviewer effect, i.e. the unintended influence on the interviewee through the interviewer (Czaja and Blair, 2005). In our survey we did not detect such an effect.

Conclusions

The data derived from our interview survey indicate that cetacean–fishery interactions are frequent in Galicia, although negative consequences for fishers and cetacean bycatch levels were mostly classified by fishers as low to moderate. Nevertheless some interactions may lead to serious conservation and/or economic problems. Our preliminary calculations suggest that bycatch rates for both common dolphin and bottlenose dolphin are likely to be unsustainable. It is therefore essential to improve the situation of affected fisheries and cetacean populations through the implementation of appropriate management plans, the success of which largely depends on fishers' willingness to cooperate, apart from legal enforcement and monitoring (Campbell and Cornwell, 2008). There are many cases where cetacean bycatch levels have been successfully reduced with the direct co-operation of fishers (IWC, 1994). Fishers have expertise with fishing gears and should therefore be involved in the creation and trial of new gear technologies. Their active participation in dolphin-watching activities, as well as the promotion of eco-labelling of fish and fishery products could even help to improve earnings (e.g. Salomon *et al.*, 2011). If the large scale use of pingers is considered as a management option, long-term scientific trials need to be conducted to determine which type of pinger is most effective and least likely to cause habituation in dolphins. It could also prove useful to put cameras on nets to verify the cetacean species that cause damage to gear, at what point during fishing activities bycatch occurs, and how many fish are actually removed or damaged, in order to direct research and mitigation measures on a more species- and gear-specific basis.

Supplementary data

The questionnaire form used for the interview survey (translated into English) is available at *ICES Journal of Marine Science* online.

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